# Satellite Observations of Tropospheric Ammonia and Carbon Monoxide: Global Distributions and Correlations and Comparisons to Model Simulations

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## Abstract

**Tropospheric Emission Spectrometer (TES):**

- NASA Aura satellite launched in 2004.
- Global tropospheric species relevant to studies of air quality, atmospheric chemistry and transport.
- Observed seasonal and global distributions of ammonia (NH3) and carbon monoxide (CO).
- Primary pollutants emitted from both common and distinct sources associated with human activities.
- Precursors of tropospheric aerosol formation and ozone production.

**Distributions and correlations of NH3 and CO from TES and GEOS-Chem model simulations:**

- Comparisons between satellite observations and model results are used to help evaluate the global and seasonal pollutant sources prescribed in the model.
- Performing the retrieval-model comparisons and distinguishing the information gained in satellite species retrievals from the *a priori* knowledge are challenging tasks.
  - We describe the characteristics of TES NH3 and CO retrievals and the method that was applied for TES and model data analyses in order to illustrate these challenges.

## 1. Representative Tropospheric Volume Mixing Ratio (RTVMR): TES and GEOS-Chem

**Two Considerations**

- GEOS-Chem species profiles need to be adjusted to the TES 'retrieved' profiles via applying TES retrieval operator for proper comparisons to TES.
- The comparisons are done in RTVMR to represent where in the profile the observations have the most information.

**TES and GEOS-Chem Data for This Presentation**

- Data sources: TES Lite products (V005 GSs and SOs) and GEOS-Chem daily data;
- Four seasons: Dec2008-Feb2009, Mar-May 2009, Jun09 & Jul-Aug 2008, Sep-Nov 2008;

**Procedure**

- Match TES NH3 & CO with Quality screened for each season;
- Calculate TES CO RTVMR at NH3_RTVMR_Pressures;
  - Map CO to RTVMR levels
- Sampling GEOS-Chem NH3 and CO data at TES matched time/locations for a season;
- Calculate GEOS-Chem NH3 and CO RTVMRs
  - Map CO/NH3 to forward model levels,
  - Apply 'TES observational operator' to profiles,
  - Inverse Map to RTVMR levels.

**Examples**
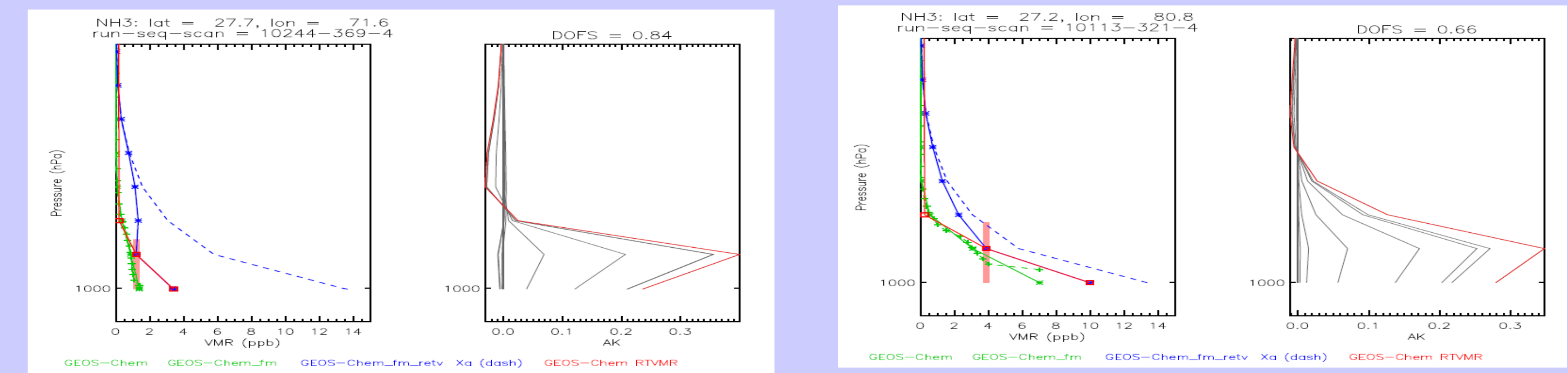


## 2. Global and Seasonal Distributions of NH3 and CO in 2008-2009: TES and GEOS-Chem
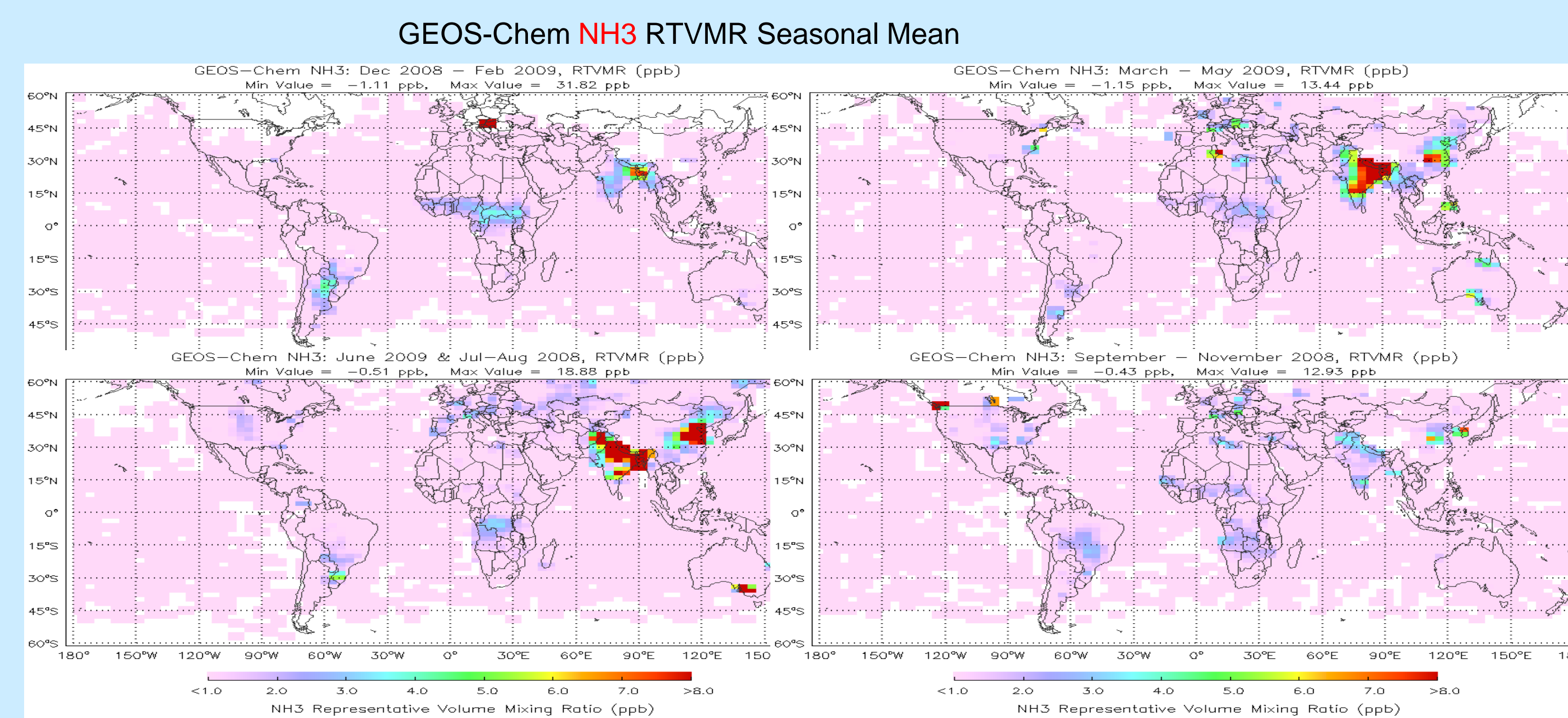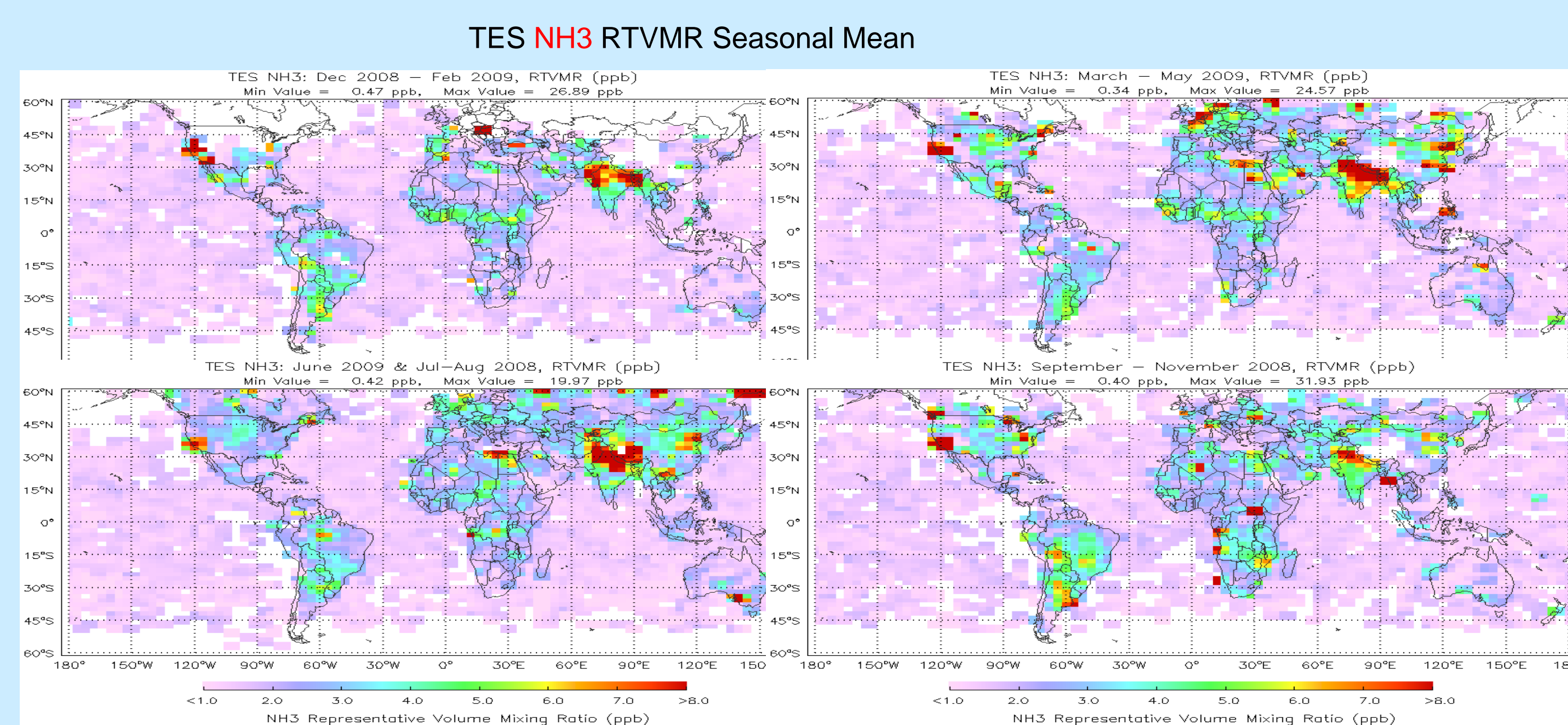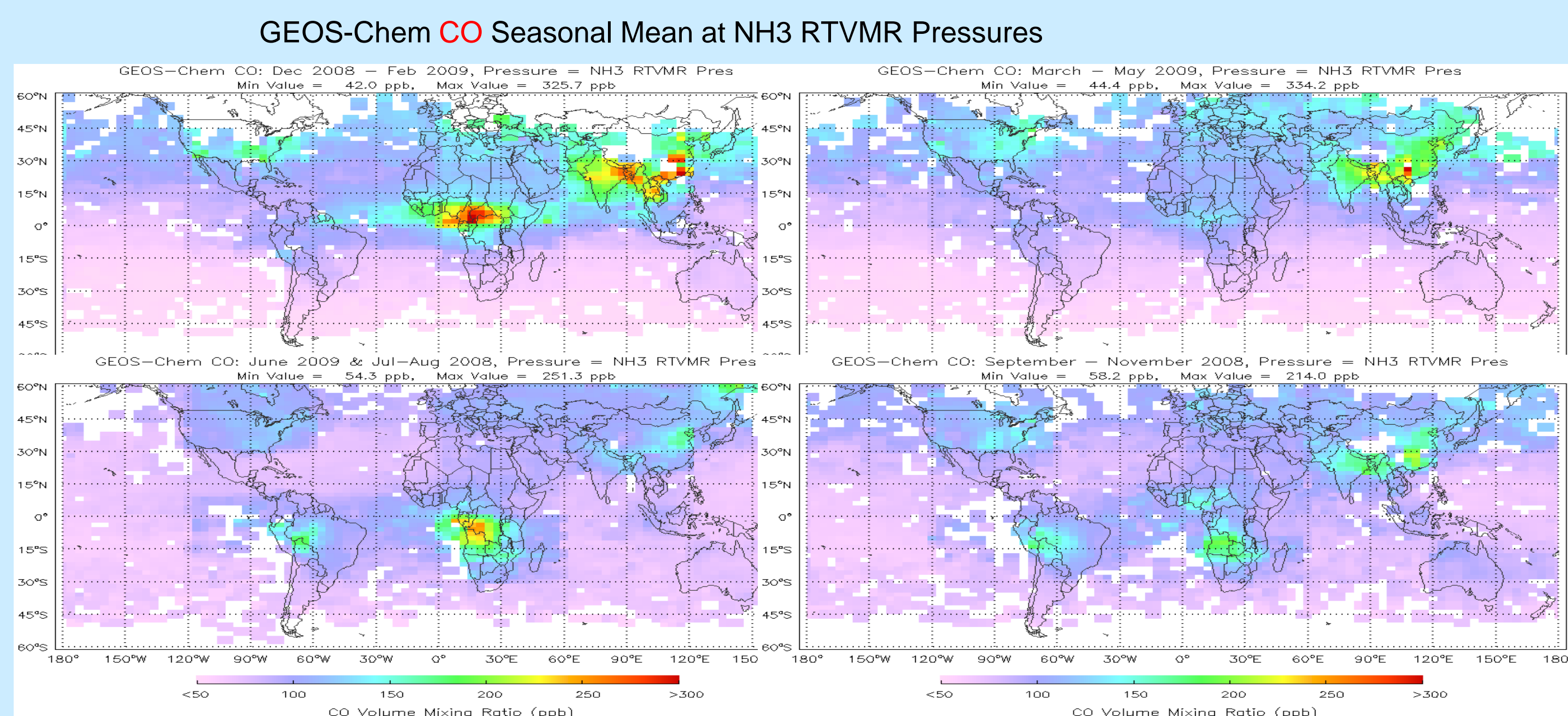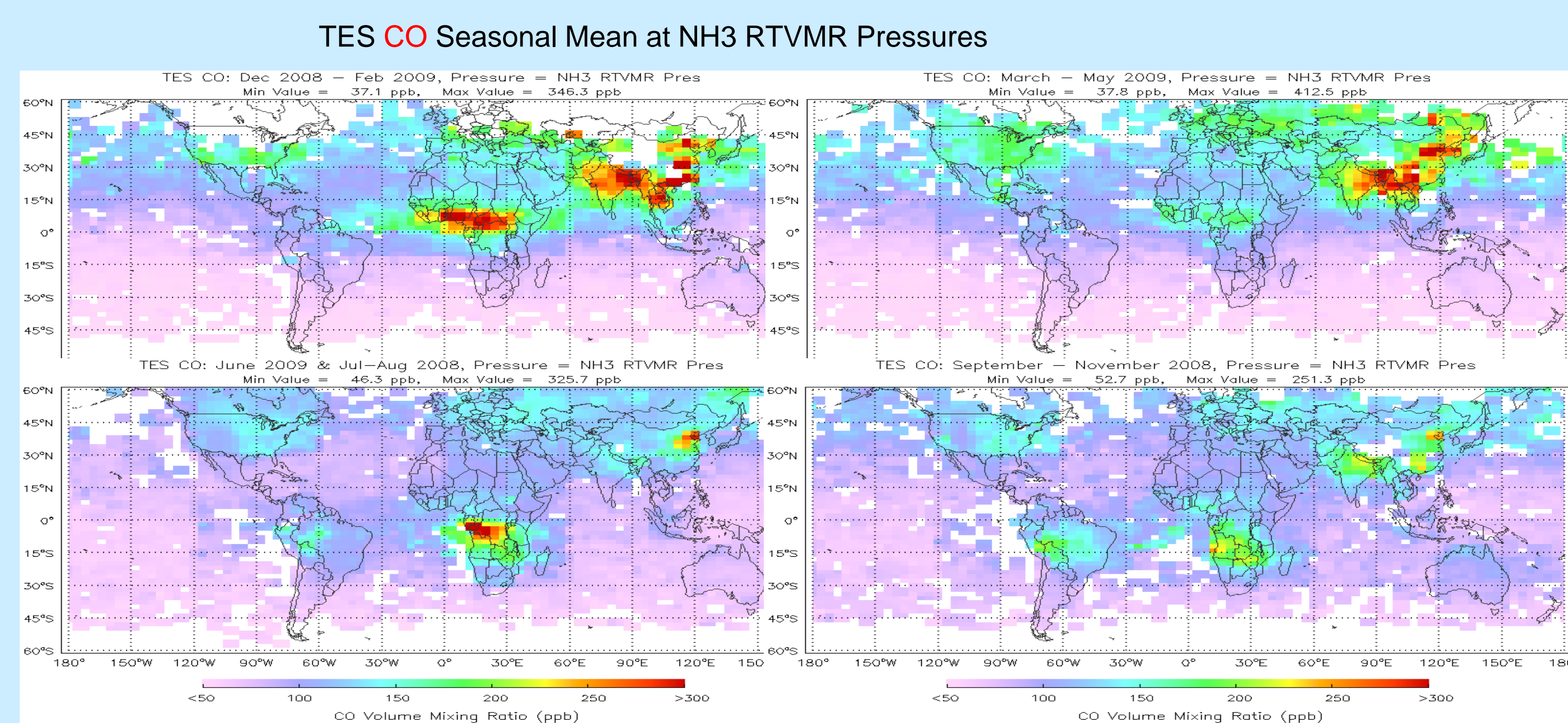


**CO Distributions:**

- Accumulations in northern hemisphere winter/spring due to long lifetime (days in summer; weeks in winter).
- Biomass burning sources:
  - Dec-Feb, NC Africa
  - Jul-Sep, SC Africa
  - Aug-Oct, S America
- Forest or bush fires: spring/summer mid-high lat
- Industry/traffic/agriculture emissions: China/India and other populated places.

**NH3 Distributions:**

- Enhancement over source regions due to short lifetime (hours to a day).
- Evidences of enhancements due to biomass burnings indicated by the CO fields.
- Enhancements in regions with know agriculture sources (e.g., Indian and surrounding areas, California central valley)

**TES CO:** Agree well with other satellite observations and in-situ data. Degree of freedom for signal is <2.

**TES NH3:** Detects seasonal enhancements with a detection limit per profile of ~ 1ppb. The total retrieval errors is 10-40%. Some hot spots need investigation.

**GEOS-Chem CO:** Agree well with satellite observations in global seasonal distributions. Lower in RTVMR compared to observations, indicating weak emission or vertical transport.

**GEOS-Chem NH3:** In general agree with TES in enhancement regions. Several uncertain factors contribute in quantifying the NH3 distributions: emission sources / bi-directional fluxes, sinks, atmospheric chemistry and transport systems.

## 3. Evidence of Elevated CO and NH3 in a Fire Plume
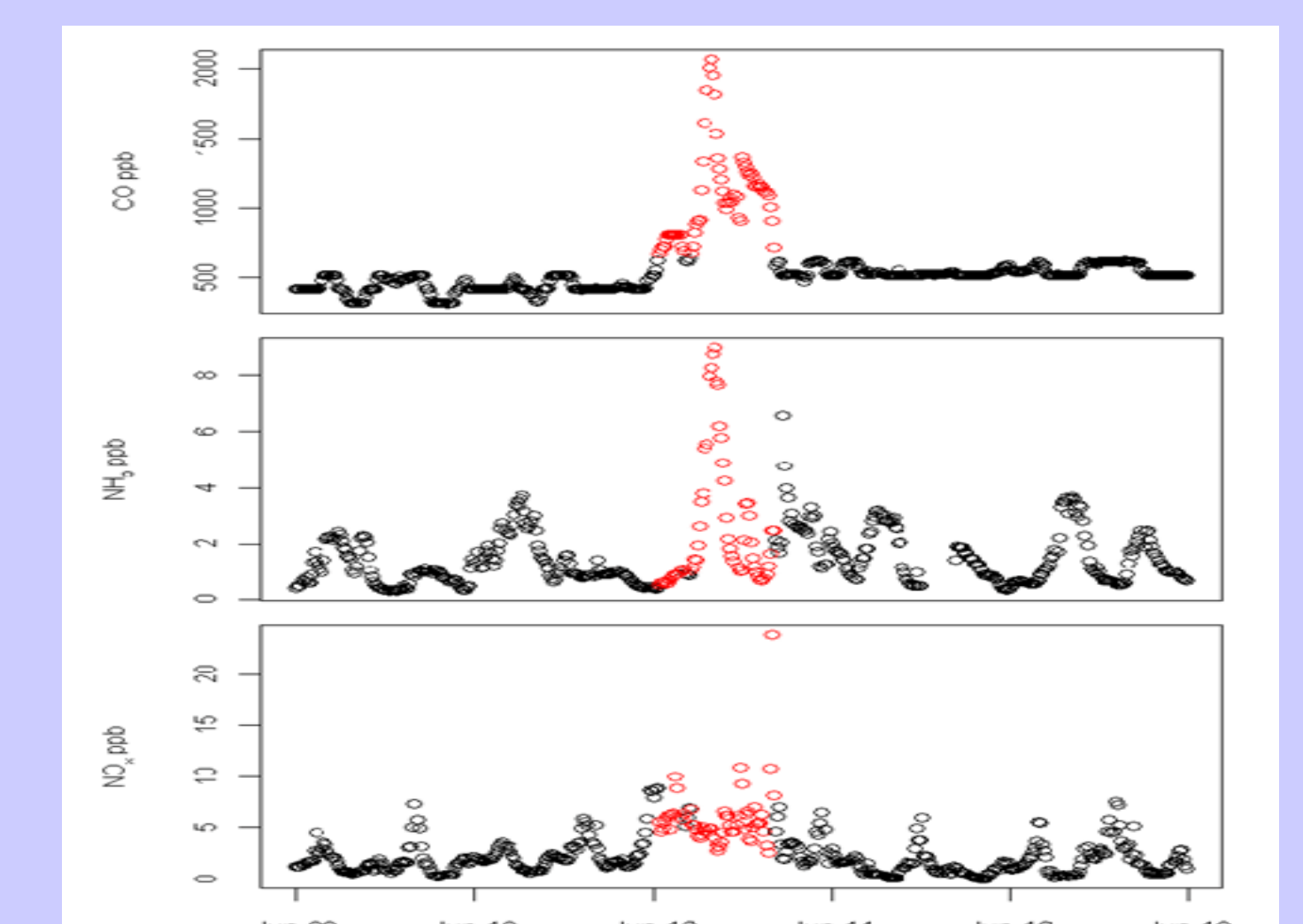


The above plot shows Duke Forest CO, NH3 and NOx observations before, during (red) and after being impacted by a plume from the 2008 fires in Washington, Hyde and Tyrrell counties. These observation are made near surface. The enhancements of CO and NH3 are well correlated in the fire plume.

## 4. Correlations of NH3 and CO: TES and GEOS-Chem Comparisons

Data from six regions shown in the boxes below are selected to examine the correlations between NH3 and CO in TES and GEOS-Chem RTVMR.
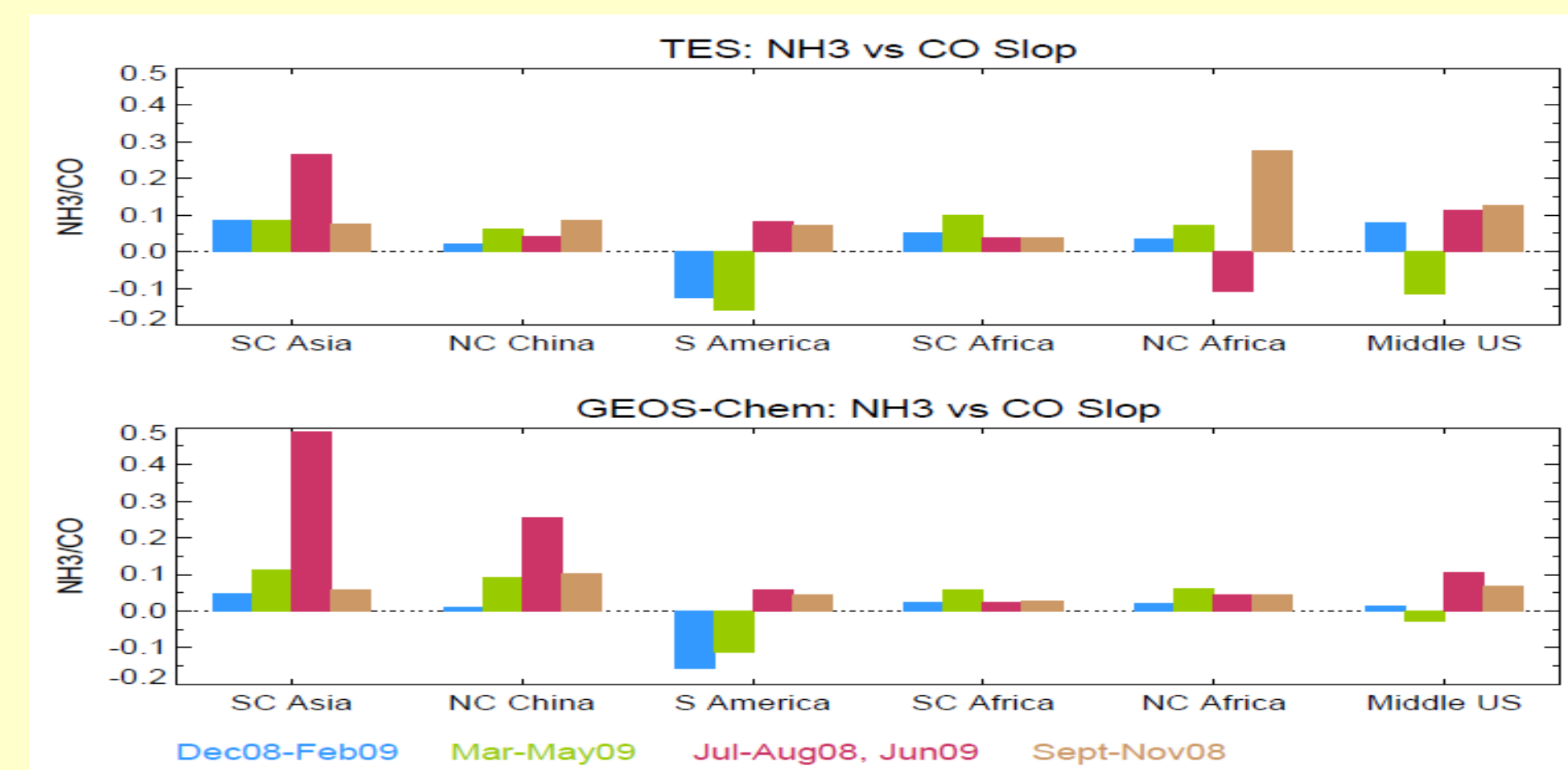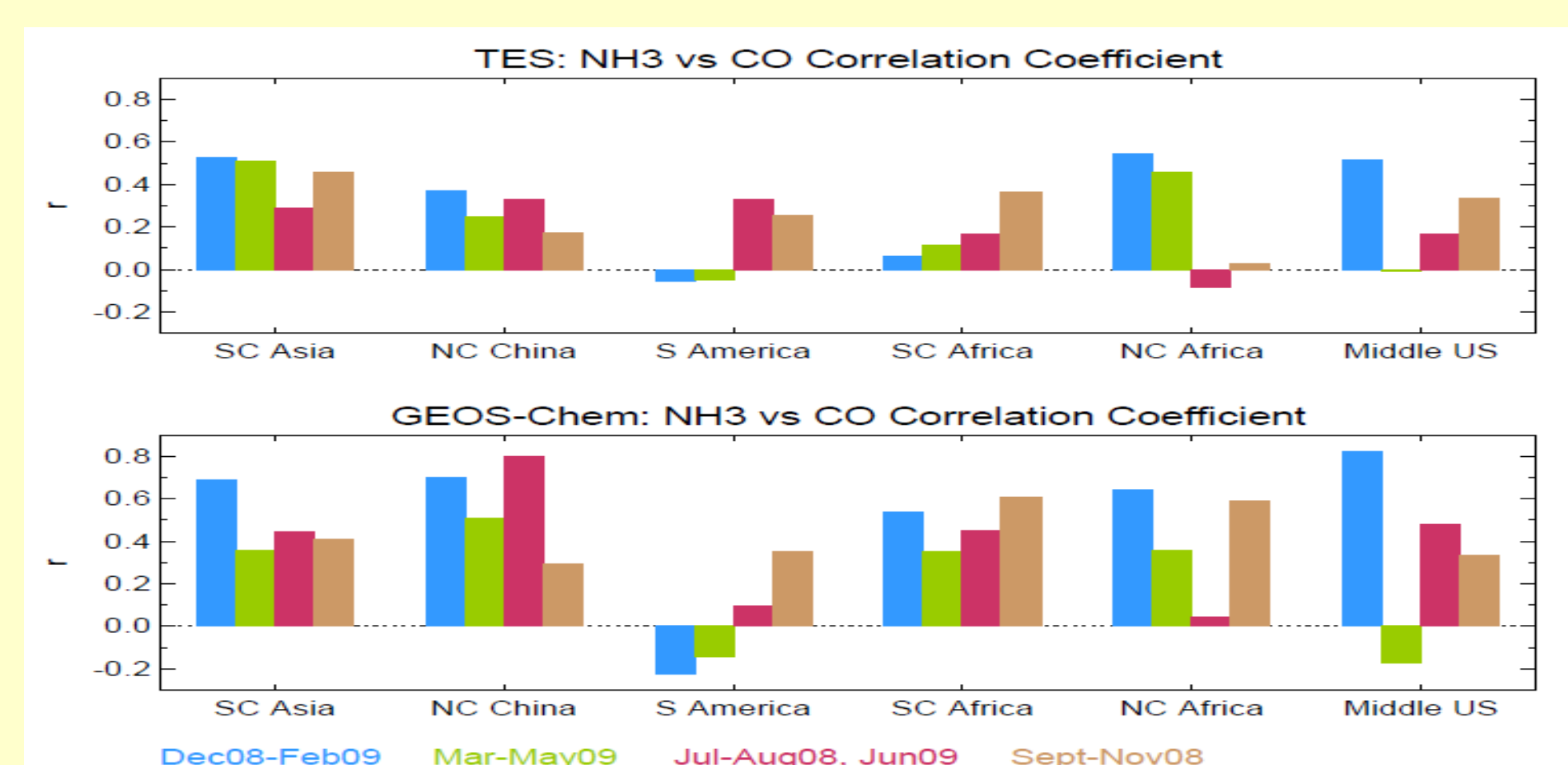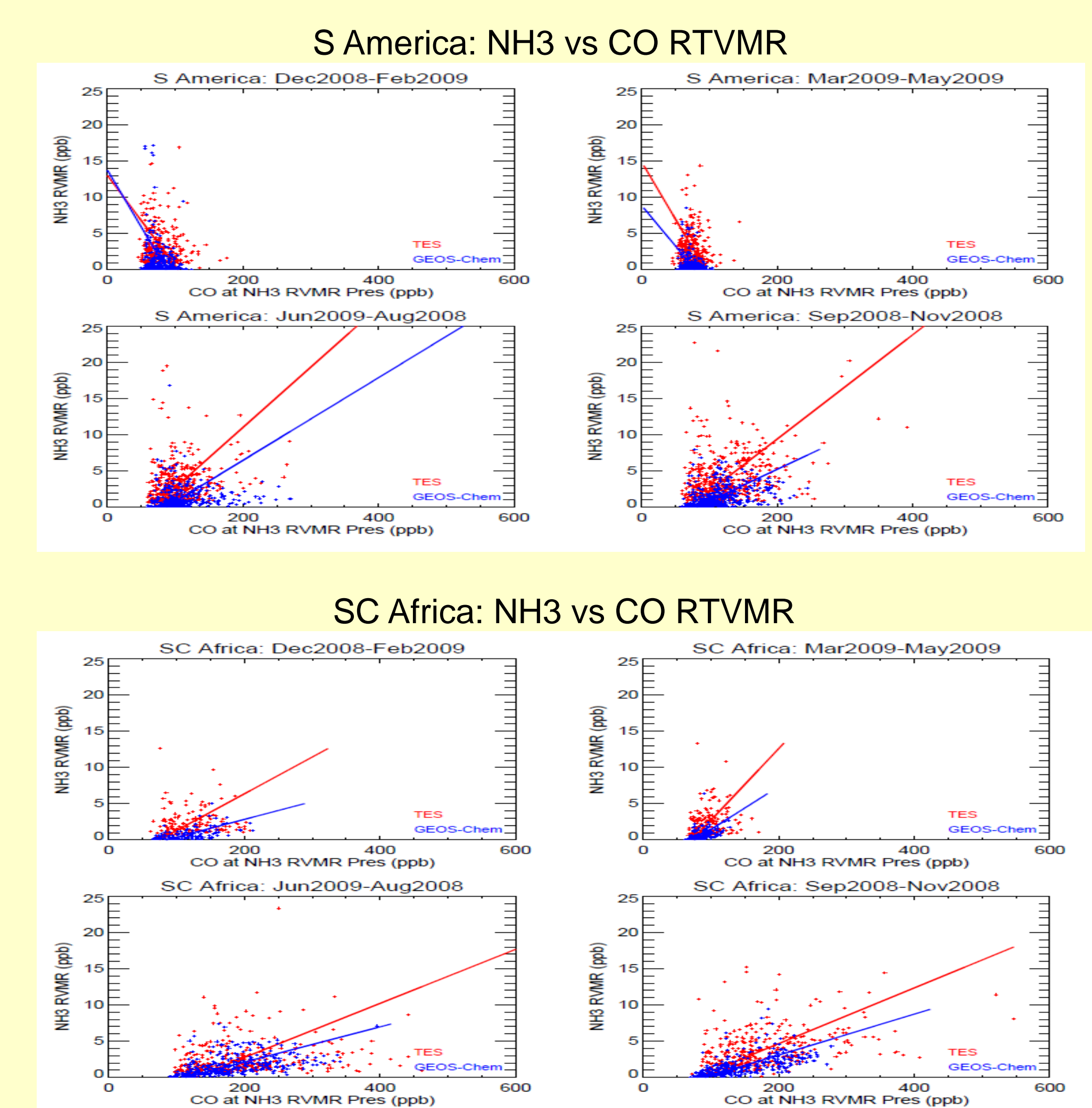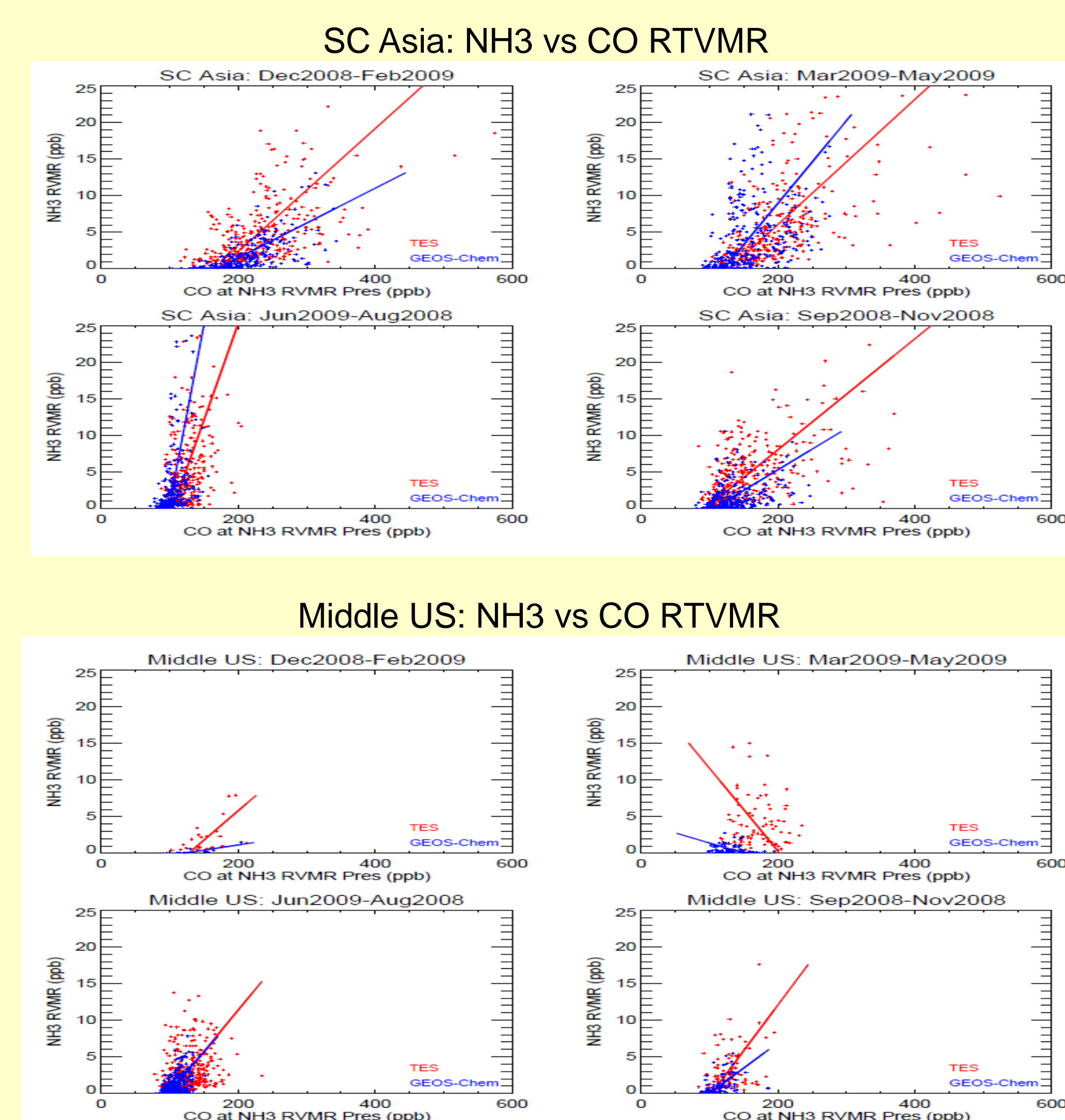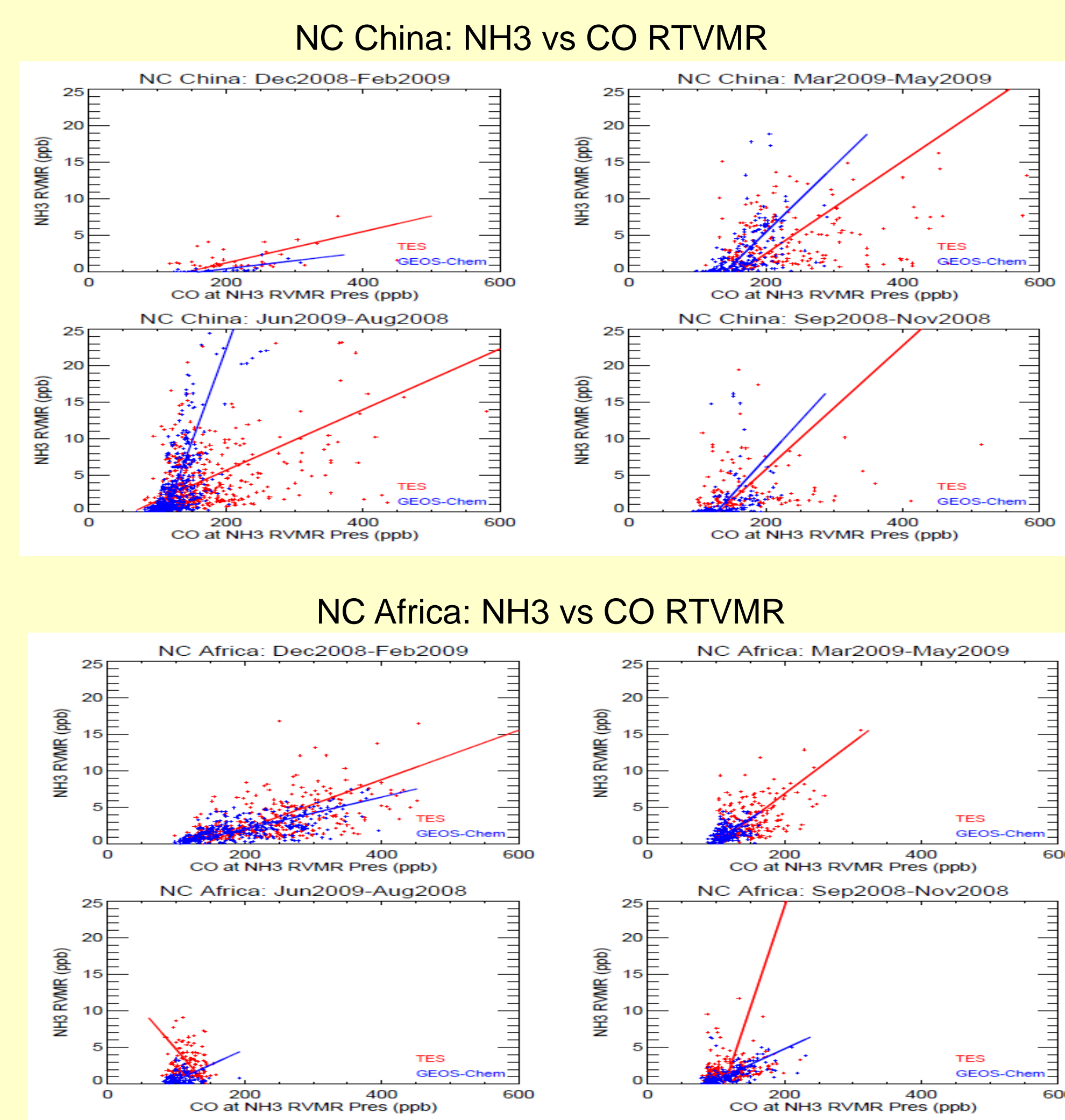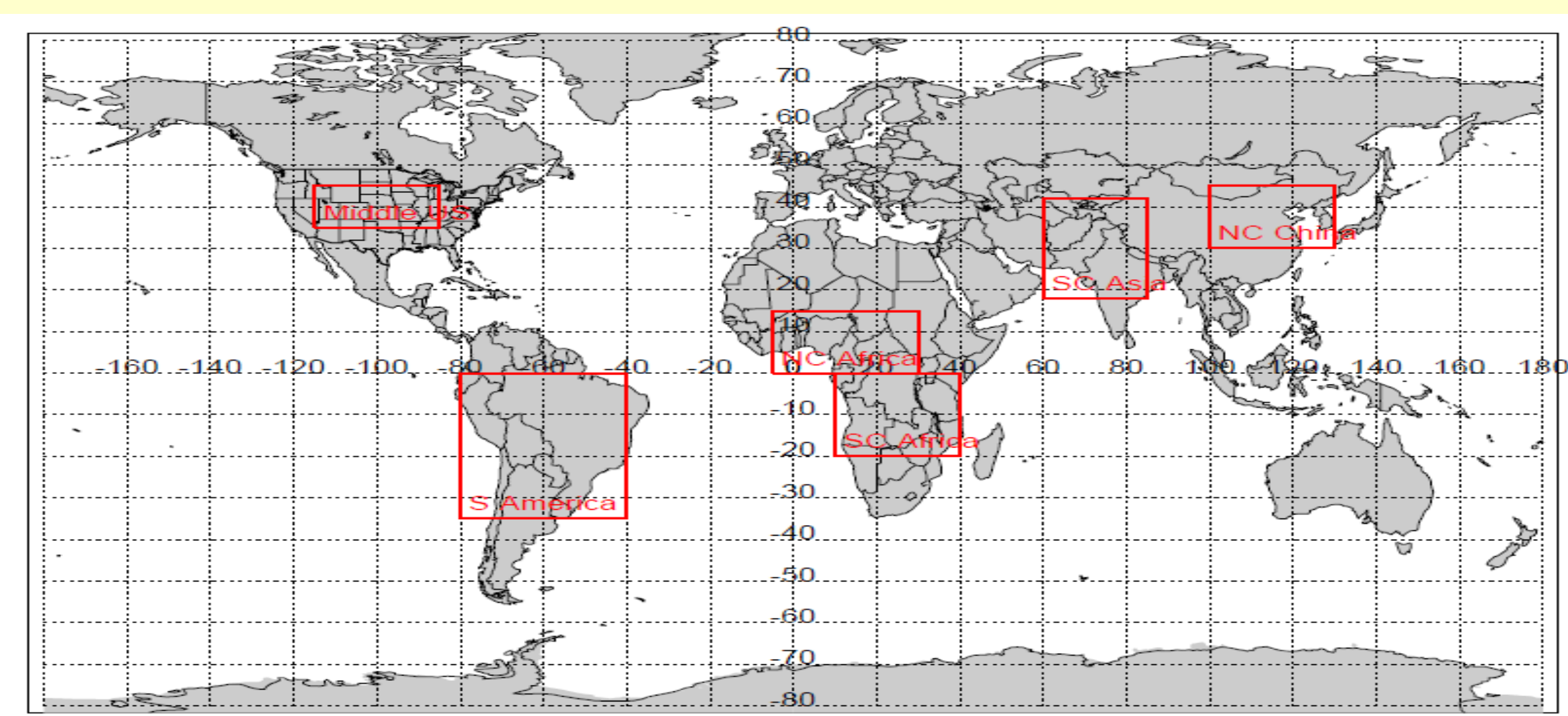


**NH3-CO Correlations:**

- Relative weak correlation coefficients in most regions due to different sources and lifetimes of the two species.
- TES and GEOS-Chem agree in NH3/CO ratios in most regions and seasons.
- In biomass burning regions, e.g., NC or SC Africa, S America, the strong positive correlations between the two species in dry seasons and much weaker correlation in other seasons are shown in both TES and GEOS-Chem.
- The correlations are stronger in GEOS-Chem than that of TES.